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DIURNAL FORCING OF PLANETARY ATMOSPHERES

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Dr. Robert M. Haberle, Technical Officer

Theoretical Studies Branch, 245-3

National Aeronautics and Space Administration

Ames Research Center

Moffett Field, California 94035-1000

Prepared by

Dr. Howard C. Houben, Principal Investigator

Space Physics Research Institute

572 Hyannis Drive

Sunnyvale, California 94087-1315

(408) 736-9705

Abstract

The Mars Climate Model developed by the Ames Research Center is a unique tool for the study of longterm atmospheric transport on both the Earth and Mars. This computer model combines the full dynamics of an atmospheric general circulation model, a sophisticated tracer transport scheme, a full hydrological cycle, and a subsurface soil model. In its terrestrial application, the model combines a stratospheric general circulation model with the same tracer transport scheme, a specialized lower boundary condition forcing procedure, data assimilation capabilities, and aerosol microphysical modeling.

Recent accomplishments utilizing these models include a definitive explanation of the current Martian water cycle. It has been demonstrated that when the combined atmosphere-polar cap-regolith system is properly modeled, it is possible to reproduce the observed seasonal patterns of water vapor column, surface frost, and low-latitude cloudiness. In addition, predictions about the subsurface reservoir of adsorbed water and about the global-average physical properties of the soil can be made. Similarly, in the case of the Earth, detailed modeling of the well-observed El Chichon and Mt. Pinatubo aerosol clouds has been successfully achieved. These case studies demonstrate the crucial importance of cloud self-heating, static stability, and inertial stability in controlling the spread (and hence the climatic impact) of volcanic clouds.

Introduction

The purpose of this research effort has been to develop a sophisticated computer model for the simulation of tracer transport (over seasonal and longer time scales) in the atmospheres of the terrestrial planets. In order to accomplish this goal, it has been necessary to incorporate detailed physical parameterizations into the integrations of a fast, primitive equation, spectral atmospheric general circulation model. This phase has largely been completed and papers describing the first results of the combined models have been submitted or are in preparation. Future research will exploit what is now a unique resource for the study of water on Mars and volcanic aerosols on the Earth.

Accomplishments

Now that the model construction phase of this research is essentially complete, the accomplishments of the past year are most easily described in terms of the physical phenomena that have been successfully modeled, and therefore, these accomplishments are distinguished by the planet to which they apply:

Mars Climate Model

Mars is the most Earth-like planet in terms of its atmospheric phenomena. It therefore is a prime target for robotic and human exploration. Understanding the general circulation of this atmosphere is thus of great importance -- to confirm our scientific understanding of the dynamics of the Earth's atmosphere and for practical purposes in dealing with the weather. Through a long series of perpetual winter simulations with our Mars Climate Model, we have shown that the radiative forcing of the thin Martian atmosphere can be well parameterized in terms of a Newtonian relaxation with a 2-day timescale. The resultant mean zonal winds, overturning Hadley circulation, and baroclinic eddies conform to our best understanding of the Martian atmosphere. The dominance by very long wave eddies distinguishes Mars' lower atmosphere from that of the Earth (making it more closely resemble the Earth's stratosphere). These findings are the subject of a paper in preparation. Using the forcing parameterization indicated above, we have conducted more than 60 years of simulation of Martian meteorology.

This planet is distinguished by very pronounced inter-annual variability (as evidenced, for example, in the irregularity of global dust storms). We have shown that our model also exhibits substantial inter-annual variability in its eddy activity during the southern spring (dust storm season) and that this eddy activity is strongly tied to the retreat of the seasonal polar cap. A paper discussing the inter-annual variability of the Martian atmosphere is in preparation. Understanding the Martian water cycle, which has puzzled scientists for years, has been the main motivation for the development of the Mars Climate Model. We have now successfully modeled the current observed cycle and have pointed out the crucial role played by the Martian regolith in regulating the southward transport of water. As a bonus, we can quantitatively estimate the global-average adsorptivity of the Martian soil, seasonal variations of the atmospheric water column and the adsorbed reservoir, the extent of frost deposits, and low-latitude cloudiness ("Modeling the Martian Water Cycle," submitted to the LPI Workshop on Evolution of Martian Volatiles). A paper describing these findings is in preparation. We have also established a world-wide web home page (URL http://humbabe.arc/~houben/vapor.html) that summarizes these findings and points to graphics and animations which support them. The meteorology of the Mars Climate Model is also the basis of the Mars Today world-wide web page (URL http://humbabe.arc /MarsToday.html) which receives about 1000 hits per month from around the world.

Terrestrial Studies

Volcanic aerosols in the Earth's stratosphere can have a measurable impact on the weather. It is therefore important to model these clouds to quantify our understanding of the meteorological feedbacks associated with stratospheric absorbers and also to assess the possible effects of very massive eruptions (both past and future). Over the last fifteen years, two major eruptions injected substantial material into the stratosphere that could be observed by satellites, aircraft, and groundstations. This has given us a wealth of data with which to calibrate our model. We have identified two distinct phases in the dynamical evolution of volcanic clouds: 1) an initial strongly-forced self-heating phase (lasting perhaps two months for a Pinatubo-sized eruption) during which the cloud moves rapidly in the vertical and horizontal directions; and 2) a quiescent phase dominated by the slow sedimentation of aerosol particles. A paper documenting our findings on this first phase for the El Chichon and Mt. Pinatubo eruptions has been submitted to Geophysical Research Letters. Material concentrating on the role of inertial stability in controlling the horizontal (latitude) spread of the cloud was presented at the 1995 Fall Meeting of the American Geophysical Union (AGU): "Early Dispersion of the El Chichon and Mt. Pinatubo Aerosol Clouds," *EOS* **76**, F127, 1995. Our attempts to characterize the nucleation and coagulation processes which in turn determine the sedimentation timescales for the cloud are described in two other papers (Hamill *et al.*, 1995a and 1995b). Completion of the modeling of this phase of the cloud history is a goal for the coming year. During that time a comprehensive paper on volcanic clouds will be completed. A preliminary version of this material has been formulated into a world-wide web home page with linked graphics and animations (URL http://humbabe.arc /~houben/massie.html). Some of the material thus made available to other investigators was presented in the review of UARS results at the 1995 Fall AGU Meeting.

References

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